

## Use of PCMs in heat sinks for electronic components

The present invention relates to the use of phase change materials in cooling devices for electrical and electronic components.

5 In industrial processes, heat peaks or deficits often have to be avoided, i.e. temperature control must be provided. This is usually achieved using heat exchangers. In the simplest case, they may consist merely of a heat conduction plate, which dissipates the heat and releases it to the ambient air, or alternatively contain heat transfer media, which firstly transport the heat from one location or medium to another.

10 The state of the art (Figure 1) for the cooling of electronic components, such as, for example, microprocessors (central processing units = CPUs) (2), are heat sinks made from extruded aluminium, which absorb the heat from the electronic component, which is mounted on support (3), and release it to the environment via cooling fins (1). The convection at the cooling fins is almost  
15 always supported by fans.

Heat sinks of this type must always be designed for the most unfavorable case of high outside temperatures and full load of the component in order to avoid overheating, which would reduce the service life and reliability of the components. The maximum working temperature for CPUs is between 60 and  
20 90°C, depending on the design.

As the clock speed of CPUs becomes ever faster, the amount of heat they emit jumps with each new generation. While hitherto peak outputs of a maximum of 30 watts had to be dissipated, it is expected that cooling capacities of up to 90 watts will be necessary. These outputs can no longer be  
25 dissipated using conventional cooling systems.

For extreme ambient conditions, as occur, for example, in remote-controlled missiles, heat sinks, in which the heat emitted by electronic components is absorbed in phase change materials, for example in the form of heat of melting, have been described (USP 4,673,030, EP 116503A, USP 4,446,916).

5 These PCM heat sinks serve for short-term replacement of dissipation of the energy into the environment and cannot (and must not) be re-used.

Known storage media for the storage of sensible heat are, for example, water or stones/concrete or phase change materials (PCMs), such as salts, salt hydrates or mixtures thereof, or organic compounds (for example paraffin) for  
10 the storage of heat in the form of heat of melting (latent heat).

It is known that when a substance melts, i.e. is converted from the solid phase into the liquid phase, heat is consumed, i.e. absorbed, and is stored as latent heat so long as the substance remains in the liquid state, and that this latent heat is liberated again on solidification, i.e. on conversion from the liquid  
15 phase into the solid phase.

The charging of a heat storage system basically requires a higher temperature than can be obtained during discharging, since a temperature difference is necessary for the transport/flow of heat. The quality of the heat is dependent on the temperature at which it is available: the higher the  
20 temperature, the better the heat can be dissipated. For this reason, it is desirable for the temperature level during storage to drop as little as possible.

In the case of storage of sensible heat (for example by heating water), the input of heat is associated with constant heating of the storage material (and the opposite during discharging), while latent heat is stored and discharged at  
25 the melting point of the PCM. Latent heat storage therefore has the advantage over sensible heat storage that the temperature loss is restricted to the loss during heat transport from and to the storage system.

The storage media employed hitherto in latent heat storage systems are usually substances which have a solid-liquid phase transition in the temperature range which is essential for the use, i.e. substances which melt during use.

5 Thus, the literature discloses the use of paraffins as storage medium in latent heat storage systems. International patent application WO 93/15625 describes shoe soles which contain PCM-containing microcapsules. The PCMs proposed here are either paraffins or crystalline 2,2-dimethyl-1,3-propanediol or 2-hydroxymethyl-2-methyl-1,3-propanediol. The application  
10 WO 93/24241 describes fabrics having a coating comprising microcapsules of this type and binders. Preference is given here to paraffinic hydrocarbons having from 13 to 28 carbon atoms. European Patent EP-B-306 202 describes fibers having heat-storage properties in which the storage medium is a paraffinic hydrocarbon or a crystalline plastic, and the storage material is  
15 integrated into the basic fiber material in the form of microcapsules.

US Patent 5,728,316 recommends salt mixtures based on magnesium nitrate and lithium nitrate for the storage and utilization of thermal energy. The heat storage here is carried out in the melt at above the melting point of 75°C.

In the said storage media in latent heat storage systems, a transition into the  
20 liquid state takes place during use. This is accompanied by problems in the case of industrial use of storage media in latent heat storage systems since sealing or encapsulation is always necessary in order to prevent leakage of liquid resulting in loss of substance or contamination of the environment. Especially in the case of use in or on flexible structures, such as, for example,  
25 fibers, fabrics or foams, this generally requires microencapsulation of the heat storage materials.

In addition, the vapor pressure of many potentially suitable compounds increases greatly during melting, and consequently the volatility of the melts

often stands in the way of long-term use of the storage materials. On industrial use of melting PCMs, problems frequently arise due to considerable volume changes during melting of many substances.

5 A new area of phase change materials is therefore provided with a particular focus. These are solid-solid phase change materials. Since these substances remain solid during the entire use, there is no longer a requirement for encapsulation. Loss of the storage medium or contamination of the environment by the melt of the storage medium in latent heat storage systems can thus be excluded. This group of phase change materials is finding many  
10 new areas of application.

USP 5,831,831, JP 10135381A and SU 570131A describe the use of similar PCM heat sinks in non-military applications. A common feature of the inventions is the omission of conventional heat sinks (for example with cooling fins and fans).

15 The PCM heat sinks described above are not suitable for absorbing the peak output of components having an irregular output profile since they do not ensure optimized discharge of the PCM or also absorb the base load.

The present invention enables cooling electronic and electrical components effectively and absorbing temperature peaks.

20 The invention provides devices for cooling heat-generating electrical and electronic components having an irregular output profile, comprising a heat-conducting unit and a heat-absorbing unit which contains a phase change material (PCM).

25 This invention relates to devices for cooling electrical and electronic components (e.g., microprocessors in desktop and laptop computers both on the motherboard and on the graphics card, power-supply parts and other

components which emit heat during operation) which have a non-uniform output profile.

Cooling devices are, for example, heat sinks. Conventional heat sinks can be improved by the use of PCMs if the heat flow from the electronic component to the heat sink is not interrupted. An interruption in this sense exists if the PCM, owing to the design of the heat sink, firstly has to absorb the heat before the heat can be dissipated via the cooling fins – which results in an impairment of the performance of the heat sink for a given design.

There are various ways of ensuring that the PCM only absorbs the output peaks.

Electrical and electronic components are usually cooled using heat sinks (Figure 1) having cooling fins.

It has been found that it is advantageous to arrange the PCM in or on the heat sink in such a way that a significant heat flow to the PCM only occurs if the heat sink exceeds the phase change temperature  $T_{PC}$  of the PCM (Figure 2, Figure 3, Figure 4 and Figure 5).

It has been found that on reaching this temperature, the cooling capacity of the cooling fins is supplemented by the heat absorption by the PCM. This causes a jump in the efficiency of the heat sink. It is thus achieved that the electrical or electronic component is not overheated.

The use of PCMs in the manner according to the invention allows the use of heat sinks of lower capacity since extreme heat peaks do not have to be dissipated.

It has been found that particularly suitable phase change materials are those whose phase change temperature  $T_{PC}$  is suitably below the critical maximum temperature for the component.

Depending on the desired maximum temperature, all known PCMs are suitable. Suitable for use of the PCMs in a heat transfer medium are encapsulated materials or solid-solid PCMs which are insoluble in the heat transfer medium.

#### Brief Description of the Drawings

Fig. 1 represents a conventional heat sink.

Figs. 2-5 represent various embodiments of the heat-dissipating devices according to the invention.

A general example of the invention is explained in greater detail below.

The devices according to the invention are described with reference to an example of the cooling of CPUs (central processing units) for computers.

In the device according to the invention (Figure 2), the PCM (4) is arranged in or on the heat sink (1) in such a way that significant heat flow from the CPU (2) on the support (3) to the PCM (4) only occurs if the heat sink exceeds the phase change temperature  $T_{PC}$  of the PCM. It is thus ensured that the PCM only absorbs the output peaks.

In principle, all known PCMs are suitable for this application. For example, it is possible to use PCMs whose phase change temperature is between about  $-100^{\circ}\text{C}$  and  $150^{\circ}\text{C}$ . For use in electrical and electronic components, PCMs in the range of about  $40^{\circ}\text{C}$  to  $95^{\circ}\text{C}$  are preferred. In this case, the materials can be selected from paraffins ( $\text{C}_{20}\text{-C}_{45}$ ), inorganic salts, salt hydrates and

mixtures thereof, carboxylic acids and/or sugar alcohols. A non-limiting selection is shown in Table 1.

Material	Melting point [°C]	Melting enthalpy [J/g]	Group
Heneicosane	40	213	Paraffins
Docosane	44	252	Paraffins
Tricosane	48	234	Paraffins
Sodium thiosulfate pentahydrate	48	210	Salt hydrates
Myristic acid	52	190	Carboxylic acids
Tetracosane	53	255	Paraffins
Hexacosane	56	250	Paraffins
Sodium acetate trihydrate	58	265	Salt hydrates
Nonacosane	63	239	Paraffins
Sodium hydroxide monohydrate	64	272	Salt hydrates
Stearic acid	69	200	Carboxylic acids
Mixture of lithium nitrate and magnesium nitrate hexahydrate	75	180	Salt hydrates
Trisodium phosphate dodecahydrate	75	216	Salt hydrates
Magnesium nitrate hexahydrate	89	160	Salt hydrates
Xylitol	93-95	270	Sugar alcohols

Table 1

Also suitable are solid-solid PCMs such as diethylammonium chloride, dipropylammonium chloride, dibutylammonium chloride, dipentylammonium chloride, dihexylammonium chloride, dioctylammonium chloride, didecylammonium chloride, didodecylammonium chloride, dioctadecylammonium chloride, diethylammonium bromide, dipropylammonium bromide, dibutylammonium bromide, dipentylammonium bromide, dihexylammonium bromide, dioctylammonium bromide,

5 didecylammonium bromide, didodecylammonium bromide,  
dioctadecylammonium bromide, diethylammonium nitrate, dipropylammonium  
nitrate, dibutylammonium nitrate, dipentylammonium nitrate,  
dihexylammonium nitrate, dioctylammonium nitrate, didecylammonium nitrate,  
dioctylammonium chlorate, dioctylammonium acetate, dioctylammonium  
formate, didecylammonium chlorate, didecylammonium acetate,  
didecylammonium formate, didodecylammonium chlorate,  
didodecylammonium formate, didodecylammonium hydrogensulfate,  
didodecylammonium propionate, dibutylammonium 2-nitrobenzoate,  
10 diundecylammonium nitrate and didodecylammonium nitrate.

Particularly suitable PCMs for use in electrical and electronic components are  
those whose  $T_{PC}$  is between 40°C and 95°C, such as, for example,  
didecylammonium chloride, didodecylammonium chloride,  
dioctadecylammonium chloride, diethylammonium bromide,  
15 didecylammonium bromide, didodecylammonium bromide,  
dioctadecylammonium bromide, diethylammonium nitrate, dioctylammonium  
nitrate, didecylammonium nitrate and didodecylammonium nitrate.

Besides the actual heat storage material, the PCMs preferably comprise at  
least one auxiliary. The at least one auxiliary is preferably a substance or  
composition having good thermal conductivity, in particular a metal powder,  
metal granules or graphite. The heat storage material is preferably in the form  
of an intimate mixture with the auxiliary, the entire composition preferably  
being in the form of either a loose bed or moldings. The term moldings here is  
taken to mean, in particular, all structures which can be produced by  
25 compaction methods, such as pelleting, tableting, roll compaction or  
extrusion. The moldings here can adopt a very wide variety of spatial shapes,  
such as, for example, spherical, cubic or cuboid shapes. In addition, the  
mixtures or moldings described here may comprise paraffin as an additional  
auxiliary. Paraffin is employed in particular if intimate contact between the  
30 heat storage composition and a component is to be established during use.  
For example, latent heat storage systems can be installed with a precise fit in



5 this way for the cooling of electronic components. During installation of the heat storage system, the handling of, in particular, a molding described above is simple; the paraffin melts during use, expels air at the contact surfaces and so ensures close contact between the heat storage material and the component. Compositions of this type are therefore preferably used in devices for cooling electronic components.

10 In addition, binders, preferably a polymeric binder, may be present as auxiliaries. In this case, the crystallites of the heat storage material are preferably in finely divided form in the binder. The preferably polymeric binders which may be present can be the polymers which are suitable as binder in accordance with the application. The polymeric binder is preferably selected from curable polymers or polymer precursors, which in turn are preferably selected from the group consisting of polyurethanes, nitrile rubber, chloroprene, polyvinyl chloride, silicones, ethylene-vinyl acetate copolymers and polyacrylates. The suitable methods for incorporation of the heat storage materials into these polymeric binders are well known to the person skilled in the art in this area. One of ordinary skill has no difficulties in finding, where appropriate, the requisite additives, such as, for example, emulsifiers, which stabilize a mixture of this type.

20 For liquid-solid PCMs, nucleating agents, such as, for example, borax or various metal oxides, are preferably employed in addition.

25 Besides ensuring good heat transfer through metals (aluminium, copper, etc.) or other heat conduction structures (metal powders, graphite, etc.), the heat transfer in the heat sink may also be implemented in the form of a heat pipe (for example USP 5,770,903 for motor cooling incl. PCM).

30 In a heat sink with heat pipe (Figure 3), the interior of the heat sink (1) then has, for example, a cavity (6), which is partially filled with a liquid and/or gaseous medium. The liquid/gaseous heat transfer medium (5) is selected from the group consisting of the halogenated hydrocarbons (for example ethyl bromide, trichloroethylene or freons) and their equivalents. The design of a

heat pipe and the choice of a suitable medium presents no problems to the person skilled in the art.

Besides this medium, the cavity also contains PCM particles (4), which absorb heat as soon as the internal temperature in the heat pipe reaches the phase change temperature  $T_{PC}$ .

It has been found that encapsulated or microencapsulated PCMs and solid-solid PCMs which are insoluble in the medium are particularly suitable. All known PCMs can be used.

Surprisingly, it has been found that, due to the good mixing of the PCM/medium suspension, the dynamics of the heat sink are particularly great.

A further possibility has been found through a mixed form (Figure 4). The CPU (2) is again mounted on a support (3). In order to improve the heat conduction, cooling fins (7) are run through the cavity (6), which is in turn partially filled with a liquid/gaseous heat transfer medium (5). Continuous cooling fins are preferred. As in the previous variants, the cavity, besides the liquid/gaseous heat transfer medium, here too contains PCM particles (4), which absorb heat as soon as the internal temperature in the heat pipe reaches the phase change temperature  $T_{PC}$ .

The PCM can be compression molded into any desired shapes. The material can be compression molded in pure form, compression molded after comminution (for example grinding), or compression molded in mixtures with other binders and/or auxiliaries. The moldings can be stored, transported and employed in a variety of ways without problems. For example, the moldings can be inserted directly into electronic components (Figure 5). Here too, the CPU (2) is mounted on a support (3). The moldings are installed between the cooling fins in such a way that they are in intimate contact with the surfaces of the cooling fins. The thickness of the moldings is selected so that a frictional connection is formed between the fins and the molding. The moldings can

also be inserted between cooling fins/heat exchangers before the latter are connected to form a stack.

However, these types of cooling with the aid of PCMs for absorbing heat peaks are not restricted to use in computers. These systems can be used in power switches and power circuits for mobile communications, transmission circuits for mobile telephones and fixed transmitters, control circuits for electromechanical actuators in industrial electronics and in motor vehicles, high-frequency circuits for satellite communications and radar applications, single-board computers, and for actuators and control units for domestic appliances and industrial electronics.

These cooling devices can be applied to all applications in which heat, *e.g.*, heat peaks, are to be absorbed (for example motors for elevators, in electrical substations and in internal-combustion engines).

Symbol	Explanation
1	Cooling ribs
2	Central processing unit (CPU)
3	Support
4	Phase change material (PCM)
5	Liquid/gaseous heat exchange medium
6	Cavity
7	Cooling fins in cavity
Z	Entire component

Table 2: Explanation of the symbols in the figures

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

In the foregoing and in the following examples, all temperatures are set forth uncorrected in degrees Celsius; and, unless otherwise indicated, all parts and percentages are by weight.

The entire disclosure of all applications, patents and publications, cited above and below, and of corresponding German application Nos. DE 100 27 803.5, filed June 8, 2000, and DE 101 14 998.0, filed March 26, 2001, are hereby incorporated by reference.

## Examples

### Example 1

A heat sink as shown in Figure 2 is designed for a processor whose maximum operating temperature is 75°C. A phase change material having a  $T_{PC}$  of between 60°C and 65°C is selected in the cavities in

the heat sink. Sodium hydroxide monohydrate having a  $T_{PC}$  of 64°C is used.

### Example 2

A heat sink as shown in Figure 3 is designed for a processor having a maximum operating temperature of 75°C. The cavities of the heat sink contain trichloroethylene as heat transfer fluid. The PCM used is an encapsulated paraffin. Nonacosane, which has a  $T_{PC}$  of 63°C, is used. However, solid-solid PCMs are also suitable as phase change material here. Didoceylammonium nitrate is suitable for this processor as it has a  $T_{PC}$  of 66°C.

The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and, without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.